Cosmic Origins (COR) Strategic Technology and GSFC Research & Technology Development Portfolios

April 10, 2014

Current COR Technology Development Portfolio

Funding Source	Technology Development Title	PI	Organization	Start Year and Duration	Tech Area
SAT2010	High Performance Cross-Strip Micro-Channel Plate Detector Systems for Spaceflight Experiments	J. Vallerga	UC Berkeley	FY12, 3 years	UV Detectors
SAT2010	Enhanced MgF2 and LiF Overcoated Aluminum Mirrors for FUV Space Astronomy	M. Quijada	GSFC	FY12, 3 years	FUV Coatings
SAT2011	Ultraviolet Coatings, Materials and Processes for Advanced Telescope Optics	K. Balasubramanian	JPL	FY13, 3 years	UV Coatings
SAT2011	Kinetic Inductance Detector Imaging Arrays for Far-Infrared Astrophysics	J. Zmuidzinas	JPL	FY13, 2 years	Far-IR Detectors
SAT2011	High Efficiency Detectors in Photon Counting and Large Focal Plane Arrays for Astrophysics Missions	S. Nikzad	JPL	FY13, 3 years	UVOIR Detectors
SAT2012	Far-Infrared Heterodyne Array Receiver	I. Mehdi	JPL	FY14, 3 years	Far-IR Detector
SAT2012	Advanced Mirror Technology Development Phase 2	P. Stahl	MSFC	FY14, 3 years	Optics
SAT2012	Deployment of Digital Micromirror Device Arrays For Use In Future Space Missions	Z. Ninkov	RIT	FY14, 2 years	UV Spectroscopy

Dec 2013

Cross Strip MCP Detector Systems for Spaceflight

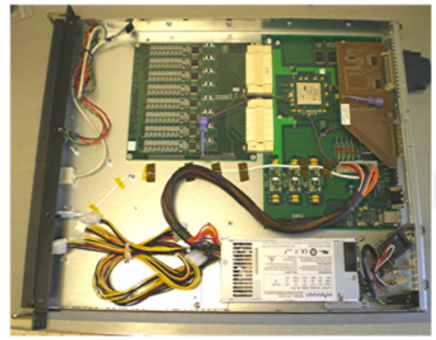
PI: John Vallerga/U.C. Berkeley

Description and Objectives:

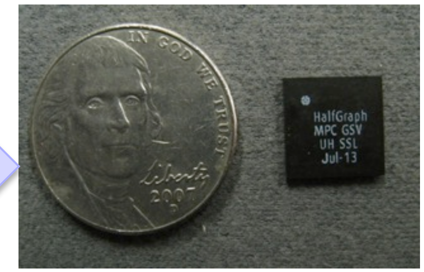
- Cross strip (XS) MCP photon counting UV detectors have achieved high spatial resolution (12µm) at low gain (500k) and high input flux (MHz) using laboratory electronics and decades old ASICs. We plan to develop a new ASIC ("GRAPH") that improves this performance, which includes amps and ADCs in a small volume, mass and power package crucial for spaceflight and demonstrates its performance to TRL 6.

Key Challenge/Innovation:

- A new ASIC with amplifiers a factor of 10 faster yet with the same noise characteristics as existing amplifier ASIC
- GHz analog sampling and a low power ADC per channel
- FPGA control of ASIC chip



Existing 19" rack mounted XS electronics



To small, low mass, low power ASIC and FPGA boards qualified for flight

Approach:

- We will develop the ASIC in stages, by designing the four major subsystems (amplifier, GHz analog sampler, ADC and output multiplexor) using sophisticated simulation tools for CMOS processes. Small test runs of the more intricate and untested designs can be performed through shared access of CMOS foundry services to mitigate risk. We plan 2 runs of the full up GRAPH design (GRAPH1 and GRAPH2). In parallel, we will design and construct an FPGA readout circuit for the ASIC as well as a 50mm XS MCP detector that can be qualified for flight use.

Key Collaborators:

- Prof. Gary Varner, U. Hawaii
- Dr. Oswald Siegmund, U.C. Berkeley

Development Period:

- May 1, 2012 – Apr 30, 2015

Milestones (assuming 3 year project):

- 50 mm detector design and fabrication (BOP + 6 mos.)
- Commission detector with PXS electronics (BOP + 1yr)
- Design and fabrication of FPGA board (BOP + 2.0yr)
- Design and fab of CSA ASIC (BOP + 0.9 mo.)
- Design and fab of Half-Graph1 ASIC (BOP + 1.75yr)
- Design and fab of Half-Graph2 ASIC (BOP + 2.5yr)

Applications:

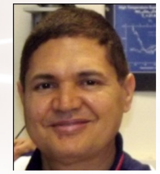
- High performance UV(1-300nm) detector for astrophysics, planetary, solar, heliospheric, or aeronomy missions
- Particle or time of flight detector for space physics missions
- Fluorescence lifetime imaging (FLIM) for biology

*TRLin = **4*** *TRLcurrent = **4*** *TRLtarget = **6***

Dec 2013

Enhanced MgF_2 and LiF Over-coated Al Mirrors for FUV Space Astronomy

PI: Manuel A. Quijada/GSFC

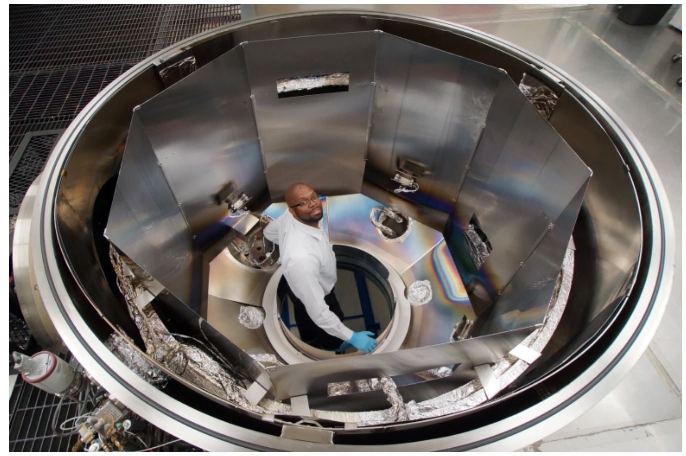


Description and Objectives:

- To develop on a large scale (up to 1 meter diameter) coating of mirrors using a Al+MgF_2 coating process to enhance performance in the Far-Ultraviolet spectral range
- Study other dielectric fluoride coatings and other deposition technologies such as Ion Beam Sputtering (IBS) that is known to produce the nearest to ideal morphology optical thin film coatings and thus low scatter

Key Challenge/Innovation:

- Improved reflective coatings for large optics, particularly in the ultraviolet part of the spectrum, could yield dramatically more sensitive instruments and permit more instrument design freedom



Inside 2-meter coating chamber after installation of thermal shroud and halogen-quartz heater lamps.

Approach:

- Retrofit a 2 meter coating chamber with heaters/thermal shroud to perform coating iterations at a high deposition temperatures (200-300°C) to further improve performance of protected Al mirrors with either MgF_2 or LiF overcoats
- Optimize deposition process of lanthinide trifluorides as high-index materials that when paired with either MgF_2 or LiF will enhance reflectance of Al mirrors at Lyman-alpha
- Establish the IBS coating process to optimize deposition of MgF_2 and LiF with extremely low absorptions at FUV wavelengths

Key Collaborators:

- Steve Rice and Felix Threat (551)
- John Lehan (SGT)
- Jeff Kruk and Charles Bowers (665)

Development Period:

- FY12 – FY14

Accomplishments and Next Milestones:

- Established the short wavelength transmission cutoff of GdF3 and LuF3 films grown by physical vapor deposition method.
- Systematic study of MgF_2 films grown with the IBS process as function of growth temperature and other coating parameters.
- Re-optimized the growth process of Al+MgF_{2+} to realize additional reflectance gains below 1200 A.
- Initial coating run of Al+MgF_2 slide distribution in 2 meter chamber: August 2013
- Design and fabricate a narrow-wavelength reflector using a dielectric stack in the 1200-1500A range: November 2013

Application:

- This technology will enable FUV missions to investigate the formation and history of planets, stars, galaxies and cosmic structure, and how the elements of life in the universe arose

TRLin = 4 ***TRLcurrent = 4*** ***TRLtarget = 5***

Dec 2013

Ultraviolet Coatings, Materials and Processes for Advanced Telescope Optics

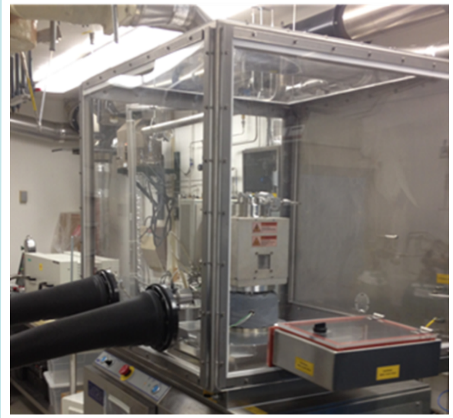
PI: Bala K. Balasubramanian/JPL

Description and Objectives:

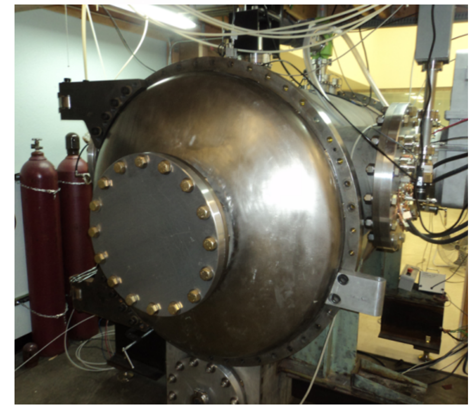
- Development of UV coatings with high reflectivity (>90-95%), high uniformity (<1-0.1%), and wide bandpasses (~100 nm to 300-1000 nm)" is a major technical challenge as much as it is a key requirement for cosmic origins program and for exoplanet exploration program. This project aims to address this key challenge and develop feasible technical solutions.

Key Challenge/Innovation:

- Materials and process technology are the main challenges. Improvements in existing technology base and significant innovations in coating technology such as Atomic Layer Deposition will be developed.



ALD chamber at JPL



1.2m coating chamber at Zecoat Corp

Approach:

- A set of experimental data will now be developed with MgF_2, AlF_3 and LiF protected Al mirrors in the wavelength range 100 to 1000 nm for a comprehensive base of measured data to enable full scale developments with chosen materials and processes.
- Enhanced coating processes including Atomic Layer Deposition (ALD) will be studied; Characterization and measurement techniques will be improved.

Key Collaborators:

- Stuart Shaklan (JPL), Nasrat Raouf (JPL), Shouleh Nikzad (JPL), Frank Greer (JPL), Paul Scowen (ASU), James Green (Univ of Colo)

Development Period:

- Jan 2013 – Dec 2015

Accomplishments and Next Milestones:

- A coating chamber has been upgraded with sources, temperature controllers and other monitors to produce coatings of various materials. Measurement tools are also established now at JPL and U of Colo.
- Coatings with various fluorides have been produced for detailed characterization (in progress).
- Enhancements to conventional coating techniques will be developed; ALD coating process tools and process will be established at JPL (2014)
- ALD and other enhanced coating processes for protected and enhanced aluminum mirror coatings will be developed and improved (2015)
- Test mirror coupons representing a meter-class mirror to be produced and characterized (2015)

Application:

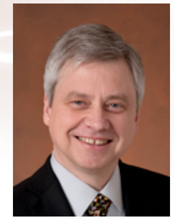
- The technology developed through this project will enable future astrophysics and exoplanet missions that aim to capture key spectral features from far UV to near infra red.

*TRLin = **3*** *TRLcurrent = **3*** *TRLtarget = **5***

Dec 2013

Kinetic Inductance Detector Arrays for Far-IR Astrophysics

PI: Jonas Zmuidzinas/Caltech

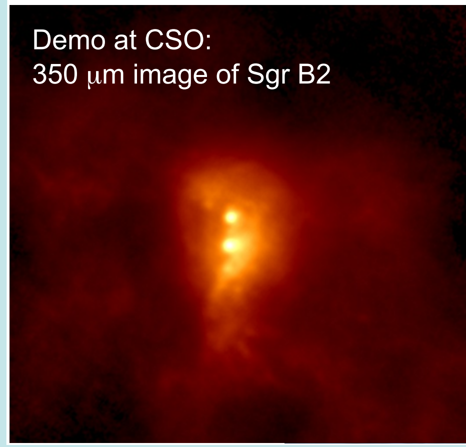


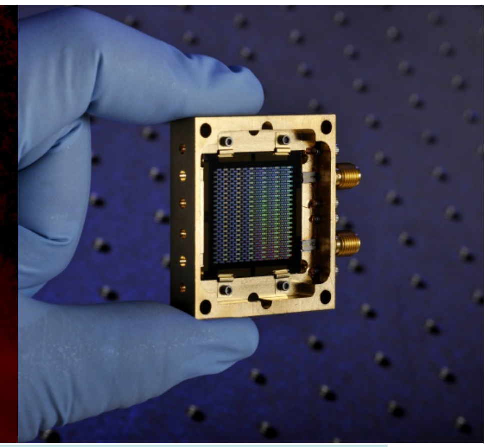
Description and Objectives:

- Half of the electromagnetic energy emitted since the big bang lies in the far-infrared. Large-format far-infrared imaging arrays are needed for studying galaxy formation and evolution, and star formation in our galaxy and nearby galaxies. Polarization-sensitive arrays can provide critical information on the role of magnetic fields.
- We will develop and demonstrate far-IR arrays for these applications.

Key Challenge/Innovation:

- Far-infrared arrays are in high demand but are difficult to fabricate, and therefore expensive and in short supply. Our solution is to use titanium nitride (TiN) absorber-coupled, frequency-multiplexed kinetic inductance detectors.





Approach:

- The goal is to raise the TRL of these detectors so that investigators may confidently propose them for a variety of instruments:
  - Ground telescope demo, 350 μm, 3×10^{-16} W Hz$^{-1/2}$
  - Lab demo for SOFIA, 90 μm, 1.7×10^{-16} W Hz$^{-1/2}$
  - Lab demo for balloon, 350 μm, 7×10^{-17} W Hz$^{-1/2}$
  - Lab demo for space, 90 μm, 5×10^{-19} W Hz$^{-1/2}$

Key Collaborators:

- G. Chattopadhyay, JPL
- Peter Day, JPL
- Darren Dowell, JPL
- Matt Holllister, Caltech
- Rick Leduc, JPL
- Chris McKenney, Caltech

Development Period:

- Jan 2013 – Dec 2014

Accomplishments and Next Milestones:

- Fall 2012: Lab demonstration at 350 μm
- Spring 2013: Successful 350 μm telescope demo at the Caltech Submillimeter Observatory (CSO) (see image above)
- Summer 2013: Lab tests of 350 μm lens-coupled arrays
- Fall 2013: First lab tests of high-sensitivity arrays

Application:

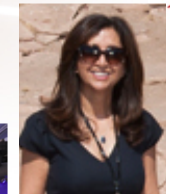
- SOFIA instruments
- Balloon payloads
- Future space mission, e.g., SAFIR/CALISTO
- Ground-based telescopes
- Applicable to both cameras and spectrometers (low NEP lab demo)
- Potential impact on mm-wave CMB instrumentation

*TRLin = **3*** *TRLcurrent = **3-6*** *TRLtarget = **4-6***

Dec 2013

High Efficiency Detectors in Photon Counting and Large FPAs

PI: Shouleh Nikzad/JPL

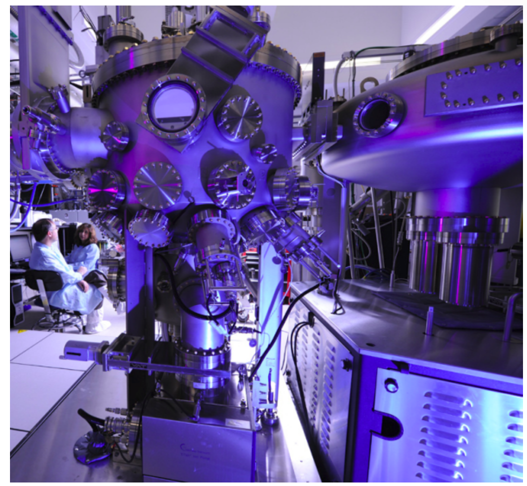


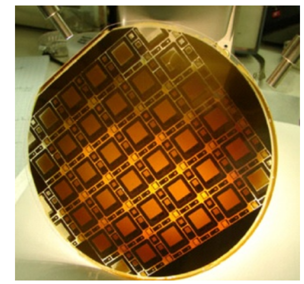
Description and Objectives:

- High efficiency, high stability imaging arrays that affordable and stable are an efficient and cost effective way to populate UV/Optical focal planes for spectroscopic missions and 4m+ UV/O telescope as stated in the NWNH 2009

Key Challenge/Innovation:

- Atomic-level control of back illuminated detector surface and detector/AR coating interface produces high efficiency detectors with stable response and unique performance advantages even in the challenging UV and FUV spectral range





Approach:

- Develop and produce 2 megapixel AR-coated, delta doped electron multiplied CCDs (EMCCDs) using JPL's 8-inch capacity silicon molecular beam epitaxy (MBE) for delta doping and atomic layer deposition (ALD) for AR coating. Perform relevant environment testing, perform system-level evaluation on sky to validate performance over a wide range of signal level

Key Collaborators:

- Chris Martin, Caltech, David Schiminovich, Columbia University, Paul Scowen, Arizona State University, Michael Hoenk, JPL

Development Period:

- Jan 2013 – Dec 2015

Accomplishments and Next Milestones:

- Wafers of 2kx1k devices have been received and back -illumination process is underway. Wafers have been bonded to handle wafer. One wafer has been thinned to 8-10 micron. Wafer is ready for delta doping and next process steps. Complete first wafer in FY13Q4
- Characterize & Validate the performance. (iterative, first in FY14Q1)
- Evaluate environmental performance. (FY14Q2, FY15Q4)
- Evaluate performance in astrophysics-relevant and mission-relevant environments. (FY15Q3, FY15)

Application:

- Large aperture UV/Optical Telescope, Explorers, Spectroscopy missions, UV/Optical imaging

*TRLin = **4***   *TRLcurrent = **4***
*TRLtarget = **5-6***

Dec 2013

A Far-Infrared Heterodyne Array Receiver for CII and OI Mapping

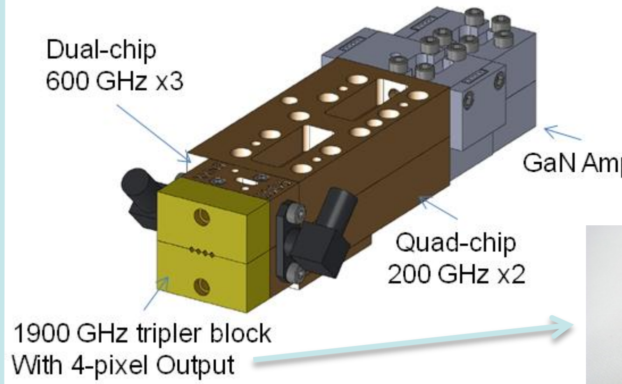
PI: Imran Mehdi/JPL

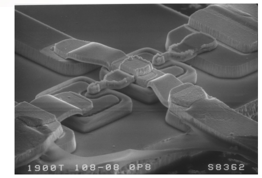
Description and Objectives:

- Heterodyne technology is necessary to answer fundamental questions such as how do stars form? How do circumstellar disks evolve and form planetary systems? What controls the mass-energy-chemical cycles within galaxies?
- We will develop LO and receiver subsystems that will allow for the implementation of multi-pixel imaging in the all important 1.9-2.06 THz range

Key Challenge/Innovation:

- Lack of solid-state sources in the THz range is perhaps the single most important challenge towards implementing array receivers
- Lack of broad IF bandwidth Hot Electron Mixers





1.9 THz diode

1.9 THz all solid-state LO source for pumping a 4-pixel heterodyne receiver

Approach:

- Utilize JPL developed membrane diode process to construct compact tunable sources in the 1.9-2.06 range
- Utilize novel waveguide based active device power combining schemes to enhance power at these frequencies
- Work with collaborators in Russia to demonstrate wide IF band Hot Electron Mixers
- Build and test multi-pixel receivers to investigate stability and field performance

Key Collaborators:

- Imran Mehdi, Jon Kawamura, Jeff Stern, Boris Karasik, Jose Siles, Choonsup Lee, Robert Lin (all JPL)

Development Period:

- Oct 2013 – Sept 2016

Accomplishments and Next Milestones:

- Demonstrated a solid-state LO source at 1.904 THz that puts out 50 microwatts of power.
- Demonstrated a bias-able 1.9 THz LO source
- Demonstration of 2.7 THz receiver with SOA performance.
- Demonstration of 4-pixel LO chain
- Development of waveguide based 4-pixel HEB mixer array
- Demonstration of 4-pixel array receiver (FY14)
- Final design of 16-pixel array receiver (FY14)

Application:

- Array receivers for SOFIA
- Heterodyne array receivers for future suborbital and space missions
- Array receivers for CCAT

*TRLin = **3***   *TRLcurrent = **3***   *TRLtarget = **4***

Dec 2013

Advanced UVOIR Mirror Technology Development for Very Large Space Telescopes Phase 2

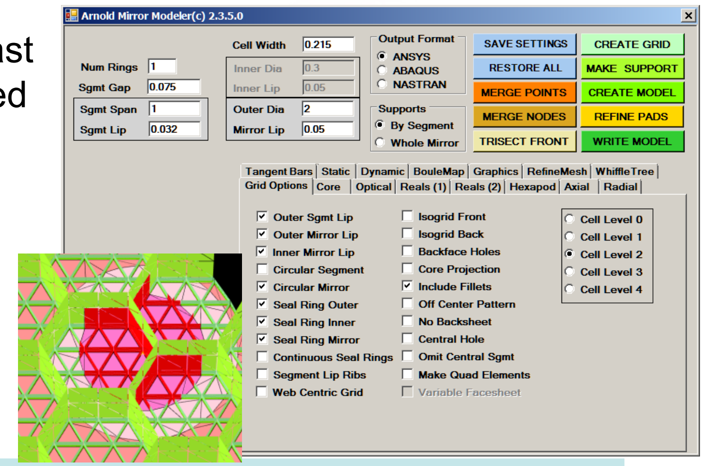
PI: Phil Stahl/MSFC

Description and Objectives:

Mature to TRL6 critical technologies needed to produce 4m or larger UVOIR mirrors such that the 2020 Decadal Review can select a UVOIR mirror to help answer fundamental science questions

- Demonstrate deep core process laterally scales from 43 cm diameter to 1.5m
- Characterize mirror optical performance from 250K to ambient
- Add capabilities to integrated design & modeling tools

Flexible, Fast and Detailed mirror modeler



Key Challenge/Innovation:

- Fabricate 1/3-scale of 4m deep core ULE® mirror
- Use integrated modeling to predict optical performance (Point Spread Function, Jitter, Encircled Energy, Wavefront Error, etc.)
- Fabricate and test a new actuator

Approach:

- Design & fabricate & test mounting & 1/3 scale mirror
- Design & fabricate mounting & test existing Extreme Lightweight Zerodur Mirror*
- Predict response of mirror tests with integrated model, investigate optimized mechanical design methods, predict on-orbit performance, refine Phase 1 point designs

*Dynamic testing cut

Key Collaborators:

- Dr. Scott Smith, Ron Eng, and Mike Effinger/ NASA MSFC
- Bill Arnold/Defense Acquisition Inc., Gary Mosier/GSFC
- Dr. Marc Postman/STScI, Laura Abplanalp, Keith Havey, Roger Dahl, Steve Maffett/ITT Excelis, Tony Hull/Univ NM/Schott

Development Period:

- Sept 2011 – Sept 2016

Accomplishments and Next Milestones:

- Updated mirror & spacecraft modelers
- Submitted 9 papers to SPIE Optics & Photonics conf./Aug. 2013
- Award Schott contract/December 2013
- Determine and reconcile Exelis SOW Tasks to available budget (Test Articles, 1/3rd Scale Mirror, etc.)/January 2013
- Initiate Exelis mirror fabrication/March 2013
- Seek one or more outside Stakeholders to join AMTD with additional budget and technical tasks

Application:

- Flagship optical missions
- Explorer type optical missions
- Department of Defense and commercial observations

TRLin = ***varies from TRL3 to TRL5.5 pending technology***
TRLcurrent = ***varies from TRL3 to TRL5.5 pending technology***
TRLtarget = ***half step increase***

Apr 2014

Development of Digital Micromirror Devices for use in Space

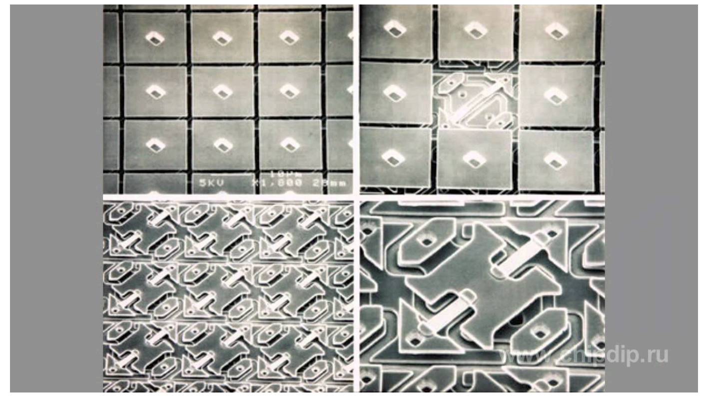
PI: Zoran Ninkov, Rochester Institute of Technology

Description and Objectives:

- There is a need for a technology to allow for selection of targets in a field of view that can be input to an imaging spectrometer for use in remote sensing and astronomy.
- We are looking to modify and develop Digital Micromirror Devices (DMD) for this application.

Key Challenge/Innovation:

- Existing DMDs need to have the commercial windows replaced with appropriate windows for the scientific application desired. Also compact, flexible control electronics need to be developed.



Approach:

- Use available 0.7 XGA DMD devices to develop window removal procedures and then replace it with a hermetically sealed Magnesium Fluoride (and other materials) window.
- Develop a radiation hard FPGA based electronics package to control the DMD.

Key Collaborators:

- NASA Goddard (Sally Heap, Manuel Quijada)
- STSCI (Massimo Robberto)
- RIT (Alan Raisanen, Antonio Mondragon)

Development Period:

- May 1, 2014 – April 30, 2016

Accomplishments and Next Milestones:

- Purchase DMDs and Pretest 7/2014
- Purchase Windows & Test 8/2018
- Re-window DMDs 11/2014
- Select Best UV Window Vendor 4/15
- GSFC Test UV XGA DMD 5/15
- Cinema DMD Re-window 1/16
- Reverse Engineered Drive Electronics 3/16

Application:

- Can be used in any hyper spectral imaging mission.
- Galaxy Evolution Spectroscopic Explorer

TRLin = ***3*** *TRLcurrent* = ***3*** *TRLtarget* = ***4***